A CSP Rehearsal Scheduler

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In this project, I create a rehearsal scheduler to automate the often tedious process of making a master tech week schedule, which requires working around 20 – 30 different student schedules. My scheduler delivers the optimal solution when possible and if not, utilizes various heuristics and probabilistic methods to approximate the best solution.

INTRODUCTION

Scheduling tech week in the world of dance and theater is a major headache for producers. It requires booking back-to-back rehearsals in the theater space, making the most out of the stage prior to opening night.

The producer of the Harvard Ballet Company has always made the tech week schedule by looking at a spreadsheet of everyone's availability and then through a method of trial-by-error, figuring out by hand the best time slots that work for the most people. However, one never knows if the final rehearsal schedule is optimal. Inevitably, there are always dancers and musicians who simply cannot make all their scheduled rehearsal times.

Approach

I have made an automated tech week rehearsal scheduler that formulates tech week scheduling as a **constraint satisfaction problem**:

- **Variables**: The hour-long slot of a choreographer's rehearsal
- **Domains**: The times that the stage is open
- **Constraints**:
  - Hard Constraints:
    - Choreographer's availability
  - Soft Constraints (that can be relaxed if necessary):
    - The dancers in the choreographer's piece availability
    - Non-Harvard college dancers have all their rehearsals scheduled on the same day

To find the best solution, I used:

- Depth first search
- MRV and LCV heuristic with backtracking
- Stochastic gradient descent

To determine the best schedule, for each solution I evaluated its optimality by weighting the constraints it violated.

Data

I had 3 data sets to evaluation my model on, each one containing the **dancer availabilities** and **tech week schedule** of a performance by the Harvard Ballet Company:

- *Oz,* Fall 2016
- *CityScapes,* Spring 2017
- *In Passage,* Fall 2017

Monday 3/20	Tuesday 3/21	Wednesday 3/22	Thursday 3/23	Friday 3/24	Saturday 3/25
FREE SPACE 10: 30 - 2	FREE SPACE 10 -2	FREE SPACE 10:30 - 1	FREE SPACE 10 -2 pm		
				FREE SPACE 1 - 6	
LIGHT FOCUSING					
EMMA blocking and lighting				ARLESIA CLEANING	
SARAH blocking and lighting		PHOEBE CLEANING			
	NETA blocking and lighting	OPENING blocking and lighting	EXTRA CLEANING	CALL AND WARM UP 6 PM	CALL AND WARM UP 6 PM
	HAZEL blocking and lighting	CALL AND WARM UP 7 PM	CALL AND WARM UP 7 PM	PERFORMANCE 1 7:30 PM	PERFORMANCE 2 7:30 PM
MICHELLE blocking and lighting	LAURA SKY blocking and lighting	DRESS REHEARSAL 1 8 - 10 PM	DRESS REHEARSAL 2 8 - 10 PM		
PHOEBE blocking and lighting	MIRIAM blocking and lighting				
ARLESIA blocking and lighting	ANNA blocking and lighting	NOTES	NOTES	RECEPTION	
TRANSITIONS 11- 12	TRANSITIONS 11-12				

Figure 1. Tech Week schedule from *CityScapes (*purple = rehearsals, grey = unavailable, blue = dress rehearsal)

Name	Monday 5 PM	Monday 6 PM	Monday 7 PM	Monday 8 PM	Monday 9 PM	Monday 10 PM	Monday 11 PM	Tuesday 6 PM	Tuesday 7 PM
EXAMPLE			Lab						
Please fill out your own availability (GREEN = free, RED = unavailable) with a brief description of the unavoidable conflict:									
Light Designer									
Monica S.									board meeting?
Choreographers									
Emma S.									
Anna A.	EMT								
Miriam H.									
Hazel L.									
Phoebe A.							Bus		
Arlesia M.		Choir Rehearsal						Lab	
Laura Sky	class								
Sarah C.							Bus		
Neta S.									
Michelle A.									
Non-Harvard Dancers									
Mary Elizabeth M.	2 to 9:30 and likely would not make it to Cambridge on time for anything								
Talia F.									
Florence K.								Class	
Violet G.								I have class	
Lilly S.							Bus		
Nicole W.			rehearsal						
Emily H.		Class until 7:45							

Figure 2. Dancer availabilities for the week of 3/19 to 3/14 for choreographers and non-Harvard college dancers

Results

Dataset	Traditional Method	CSP Solver using DFS
Oz	Violations: 10 Score: 18	Violations: 4 Score: 6
Cityscapes	Violations: 5 Score: 22	Violations: 0 Score: 19
In Passage	Violations: 8 Score: 7	Violations: 2 Score: 1

Note: We aim to minimize the score.

The CSP solver manages to find a much better solution that the manual way of creating the schedule. Furthermore, it is able to produce a solution in **on average 0.003 seconds** (while in my past experience, the process took at least 1.5 hours).

Not shown, but the heuristic method works very well as well, achievlng the same scores as the exhaustive DFS in some cases.

Conclusions

The automatic CSP scheduler provides **many advantages** over the traditional method:

- Much faster
- Find optimal solution
- Allows for flexibility
- Provides many solutions
- Easily customizable

In the future, I would like to implement a **GUI** for this program so that producers can run the scheduler without needing the code and dancers can enter their availability via a weblink. I would also like to add **explore more randomized methods**, since DFS can be time-consuming . Overall, I hope my project will be useful piece of software that the Harvard Ballet Company can use for years to come.

Project Resources

Lorterapong P, Ussavadilokrit M. Construction Scheduling Using the Constraint Satisfaction Problem Method. Journal Of Construction Engineering & Management [serial online]. April 2013;139(4):414-422. Available from: Academic Search Premier, Ipswich, MA.

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